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(71) Applicant *(for all designated States except US)*: **ELI LILLY AND COMPANY** [US/US]; Lilly Corporate Center, Indianapolis, IN 46285 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **ATKINSON, Paul, Robert** [US/US]; 4514 Lakeridge Drive, Indianapolis, IN 46234 (US). **TIAN, Yu** [CN/US]; 13695 Flintridge Pass, Carmel, IN 46033 (US). **WITCHER, Derrick, Ryan** [US/US]; 10898 Parrot Court, Fishers, IN 46038 (US).

(74) Agents: **WEBSTER, Thomas, D.** et al.; Eli Lilly and Company, Lilly Corporate Center, Indianapolis, IN 46285 (US).

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(54) Title: FLINT COMPOUNDS AND FORMULATIONS THEREOF

(57) Abstract: The present invention provides novel compounds, which comprise FLINT complexed with a divalent metal cation, pharmaceutical formulations thereof, methods for reducing and/or inducing aggregation of FLINT, and methods of using such compounds for treating or preventing diseases that may be related to the FasL/Fas interaction.

FLINT COMPOUNDS AND FORMULATIONS THEREOF

Background of the Invention

The present invention is in the field of human medicine, particularly in the treatment and prevention of disorders that may be associated with the binding of FasL to the Fas receptor. More specifically, the present invention relates to compounds and formulations of a FLINT protein.

A number of tumor necrosis factor receptor proteins ("TNFR proteins") and proteins homologous thereto have been isolated in recent years. They have many potent biological effects and aberrant activity of these proteins has been implicated in a number of disease states.

One such TNFR homologue, reported in July, 1998 (Gentz *et al.*, WO 98/30694), binds the protein FAS Ligand and thereby inhibits the activation of another TNFR homologue, FAS, by FAS Ligand (U.S. Provisional Applications Serial Nos. 60/112,577, 60/112,933, and 60/113,407, filed December 17, 18 and 22, 1998, respectively). This new protein is referred to herein as "FAS Ligand Inhibitory Protein" or "FLINT."

Over activation of FAS by FAS Ligand has been implicated in a number of pathological conditions, including runaway apoptosis (Kondo *et al.*, Nature Medicine 3(4):409-413 (1997) and Galle *et al.*, *J. Exp. Med.* 182:1223-1230 (1995)) and inflammatory disease resulting from neutrophil activation (Miwa *et al.*,. *Nature Medicine 4*:1287 (1998)).

"Runaway apoptosis" is a level of apoptosis greater than normal or apoptosis occurring at an inappropriate time. Pathological conditions caused by runaway apoptosis include organ failure, for example in the liver, kidneys and pancreas. Inflammatory diseases

associated with excessive neutrophil activation include, but are not limited to, sepsis, ARDS, SIRS and MODS.

The structural properties of proteins may be affected by divalent cations. For example, aggregation and/or precipitation of proteins, as well as oligomerization, may be induced by divalent cations. Aggregation of proteins can impact the ability to produce, purify, formulate and deliver a protein, for example, as a pharmaceutical product. Moreover, aggregation and/or oligomerization can impact the stability of a protein, for example, in storage. In some instances, a protein's stability can be enhanced if aggregated and/or precipitated prior to, or during storage.

FLINT and analogs thereof, for example, analog R218Q, aggregate and eventually precipitate from solution when exposed to divalent cation. For example, analog R218Q purified by IMAC chromatography and elution in 0.4M imidazole, precipitates from solution (See Example 5, *infra*). These observations suggest that FLINT and analogs thereof interact with divalent cations, such as Ni^{+2}, to cause aggregation and/or precipitation.

As FLINT is potentially a useful therapeutic protein, its purification and formulation are important factors to be worked out on the path to development of a pharmaceutical product. While FLINT is known from prior disclosures (See e.g WO 98/30694 and WO 99/50413), its formulation has not been thoroughly investigated, nor has the impact of divalent cation on the aggregation and/or oligomerization of the protein been sufficiently investigated for purposes of realizing the full therapeutic and pharmaceutical utility.

The present invention relates to a method for eliminating aggregation and/or precipitation of FLINT and analogs thereof, useful in purifying FLINT and its analogs comprising the removal of divalent cation from a solution or other medium comprising FLINT.

The invention relates further to the purification of FLINT and analogs thereof, from a solution of said FLINT or analog, by immobilized metal ion affinity (IMAC) chromatography, comprising removal of divalent cation from said solution.

The invention relates further to a composition comprising FLINT and a divalent metal cation.

The invention relates further to a method for producing a composition comprising FLINT, or FLINT analog, in association with a divalent cation.

The present invention relates further to a pharmacuetical formulation comprising FLINT, or FLINT analog, in association with a divalent metal cation, and with one or more pharmaceutically acceptable carriers, diluents, or excipients.

Accordingly, the present invention provides a FLINT-divalent cation complex, which comprises FLINT complexed with a divalent metal cation, pharmaceutical formulations thereof, and methods for using such compounds in the treatment and/or prevention of disorders that may be associated with the binding of Fas to FasL, and/or LIGHT to the LTβR and/or TR2/HVEM receptors.

Summary of the Invention

The invention provides a composition comprising FLINT complexed with a divalent metal cation. The invention additionally provides parenteral pharmaceutical

formulations comprising the FLINT divalent cation compositions and methods for using such compounds in treating or preventing diseases and disorders that may be associated with the binding of Fas to FasL, and/or LIGHT to LTβR and/or TR2/HVEM receptors. The invention further provides a process of preparing such compounds, which comprises combining FLINT and a divalent metal cation in an aqueous solution at a pH of about 4.5 to 9.0.

Detailed Description and Preferred Embodiments

For purposes of the present invention, as disclosed and claimed herein, the following terms and abbreviations are defined as follows:

The term "aggregate" or "aggregation" refers to a non-covalent association of protein or peptide molecules including monomers, subunits, and fragments thereof, that may lead to precipitation of said molecules.

"FLINT" is used herein to encompass native FLINT (SEQ ID NO:2), or mature FLINT (SEQ ID NO:1). The term may also refer to an analog of FLINT having one or more amino acid deletions, substitutions, or additions such that substantially the same biological activity is retained.

The term "fusion protein" or "FLINT fusion protein" as used herein refers to a FLINT protein wherein said protein or analog is fused to a heterologous protein or peptide including, for example, a peptide tag useful in purification, e.g. a His-tag.

"Treating" as used herein, describes the management and care of a patient for the purpose of combating the disease, condition, or disorder and includes the administration of a protein of the present invention to prevent the onset of the symptoms or complications,

alleviating the symptoms or complications, or eliminating the disease, condition, or disorder.

"Isotonicity agent" refers to an agent that is physiologically tolerated and embarks a suitable tonicity to the formulation to prevent the net flow of water across the cell membrane. Compounds, such as glycerin, are commonly used for such purposes at known concentrations. Other possible isotonicity agents include salts, e.g., NaCl, dextrose, and lactose.

The term "oligomer" or "oligomerization" refers to a specific interaction of more than one protein subunit in non-covalent or covalent Fashion. Examples of specific oligomers would include dimers, trimers, tetramers, etc. As used herein the term refers to association of one or more FLINT molecules including association of identical or non-identical subunits such as, for example, native FLINT in association with a FLINT analog or FLINT fusion protein. The process of oligomerization lies on a continuum with the process of aggregation, the latter representing non-specific interactions, that in the extreme, leads to precipitation.

"Physiologically tolerated buffer" refers to buffers including TRIS, sodium acetate, sodium phosphate, or sodium citrate. The selection and concentration of buffer is known in the art.

"Pharmaceutically acceptable preservative" refers to a multi-use parenteral formulation that meets guidelines for preservative effectiveness to be a commercially viable product. Pharmaceutically acceptable preservatives known in the art as being acceptable in parenteral formulations include: phenol, m-cresol, benzyl alcohol, methylparaben, chlorobutanol, p-cresol, phenylmercuric nitrate, thimerosal

and various mixtures thereof. Other preservatives may be found, e.g., in Wallhauser, K. H. Develop. Biol. Standard, 24, 9-28 (Basel, S. Krager, 1974). The concentration necessary to achieve preservative effectiveness is dependent upon the preservative used and the conditions of the formulation.

As noted above, the invention provides a compound comprising FLINT protein complexed with a divalent metal cation. A FLINT-divalent cation complex could increase the stability of the protein and enhance potency, as has been observed with other proteins. Such complexes can provide effective pharmacological treatment at lower doses thereby abrogating toxic or other undesirable side effects.

Applicants have discovered that FLINT undergoes oligomeriztion and/or aggregation in the presence of divalent cations. In one aspect of the present invention, pharmaceutical compositions of FLINT and divalent cation(s) provide depot formulations for therapeutic use. In another aspect, oligomerization and/or aggregation of FLINT can be reduced, prevented, or reversed by removal of divalent cation from said protein, or from the environment in which said protein occurs. In this aspect, the invention relates to a process or method for purifying FLINT and/or for maintaining FLINT in solution. In another aspect, the invention relates to a method to stimulate or induce oligomerization, and/or aggregation of FLINT by the addition of divalent cation to a sample of FLINT.

The presently claimed compounds comprise FLINT complexed with a divalent metal cation. A divalent metal cation includes, for example, Zn^{+2}, Mn^{+2}, Fe^{+2}, Co^{+2}, Cd^{+2}, Ca^{+2}, Ni^{+2} and the like. A combination of two or more divalent metal cations is operable; however the preferred

compounds comprise a single species of metal cation, most preferably Zn^{+2}. Preferably, the divalent metal cation is in excess; however, the molar ratio of at least one molecule of a divalent metal cation for each ten molecules of FLINT is operable. Preferably, the compounds comprise from 1 to 100 divalent metal cations per molecule of FLINT. The compounds may be amorphous or crystalline solids.

Appropriate forms of metal cations are any form of a divalent metal cation that is available to form a complex with a molecule of FLINT protein of the present invention. The metal cation may be added in solid form or it may be added as a solution. Several different cationic salts can be used in the present invention. Representative examples of metal salts include the acetate, bromide, chloride, fluoride, iodide and sulfate salt forms. The skilled artisan will recognize that there are many other metal salts which also might be used in the production of the compounds of the present invention. Preferably, zinc acetate or zinc chloride is used to create the zinc-FLINT protein compounds of the present invention. Most preferably, the divalent metal cationic salt is zinc chloride.

Generally, the claimed compounds are prepared by techniques known in the art. For example, it is convenient to combine FLINT with the desired divalent metal cation in an aqueous solution at a pH of about 4.5-9.0, preferably about pH 5.5-8, alternatively, pH 6.5-7.6. The claimed compound precipitates from the solution as a crystalline or amorphous solid. Significantly, the compound is easily isolated and purified by conventional separation techniques appreciated in the art, including filtration and centrifugation. Significantly, the protein-metal cation

complex is stable and may be stored as a solid or as an aqueous suspension.

The present invention further provides a pharmaceutical formulation comprising a compound of the present invention and water. The concentration of the FLINT protein in the formulation is about 0.1 mg/mL to about 100 mg/mL; preferably about 0.5 mg/mL to about 50.0 mg/mL; most preferably, about 5.0 mg/mL.

The formulation preferably comprises a pharmaceutically acceptable preservative at a concentration necessary to maintain preservative effectiveness. The relative amounts of preservative necessary to maintain preservative effectiveness varies with the preservative used. Generally, the amount necessary can be found in Wallhauser, K. H. Develop. Biol. Standard, 24, 9-28 (Basel, S. Krager, 1974), herein incorporated by reference.

An isotonicity agent, preferably glycerin, may be added to the formulation. The concentration of the isotonicity agent is in the range known in the art for parenteral formulations, preferably about 16 mg/mL glycerin. The pH of the formulation may also be buffered with a physiologically tolerated buffer. Acceptable physiologically tolerated buffers include TRIS, sodium acetate, sodium phosphate, or sodium citrate. The selection and concentration of buffer is known in the art.

Other additives, such as a pharmaceutically acceptable excipients like Tween 20 (polyoxyethylene (20) sorbitan monolaurate), Tween 40 (polyoxyethylene (20) sorbitan monopalmitate), Tween 80 (polyoxyethylene (20) sorbitan monooleate), Pluronic F68 (polyoxyethylene polyoxypropylene block copolymers), BRIJ 35 (polyoxyethylene (23) lauryl ether), and PEG (polyethylene

glycol) may optionally be added to the formulation to reduce aggregation.

The claimed pharmaceutical formulations are prepared in a manner known in the art, and are administered individually or in combination with other therapeutic agents. The formulations of the present invention can be prepared using conventional dissolution and mixing procedures. Preferably, the claimed formulations are prepared in an aqueous solution suitable for parenteral use. That is, a protein solution is prepared by mixing water for injection, buffer, and a preservative. Divalent metal cations are added to a total cation concentration of about 0.001 to 5.0 mg/mL, preferably 0.05 to 1.5 mg/mL. The pH of the solution may be adjusted to completely precipitate the FLINT protein-cation complex. The compound is easily resuspended before administration to a patient.

Parenteral daily doses of the compound are in the range from about 1 ng to about 10 mg per kg of body weight, although lower or higher dosages may be administered. The required dosage will be determined by the physician and will depend on the severity of the condition of the patient and upon such criteria as the patient's height, weight, sex, age, and medical history.

Variations of this process would be recognized by one of ordinary skill in the art. For example, the order in which the components are added, whether a surfactant is used, the temperature and pH at which the formulation is prepared, may all be optimized for concentration and means of administration.

The pH of the formulation is generally pH 4.5 to 9.0 and preferably 5.5 to 8.0, alternatively 6.5 to 7.6;

although more acidic pH wherein a portion or all of the protein-metal cation complex is in solution is operable.

The formulations prepared in accordance with the present invention may be used in a syringe, injector, pumps or any other device recognized in the art for parenteral administration.

The proteins used in the present compounds can be prepared by any of a variety of recognized peptide synthesis techniques including classical (solution) methods, solid phase methods, semi synthetic methods, and more recent recombinant DNA methods. Recombinant methods are preferred if a high yield is desired. The basic steps in the recombinant production of protein include:

a) construction of a synthetic or semi-synthetic (or isolation from natural sources) DNA encoding the FLINT protein,

b) integrating the coding sequence into an expression vector in a manner suitable for the expression of the protein either alone or as a fusion protein,

c) transforming an appropriate eukaryotic or prokaryotic host cell with the expression vector, and

d) recovering and purifying the recombinantly produced protein.

Synthetic genes and nucleic acids can be constructed by techniques well known in the art. Owing to the degeneracy of the genetic code, the skilled artisan will recognize that multiple DNA sequences may be constructed which encode the desired proteins. Synthesis is achieved by recombinant DNA technology or by chemical

synthesis, for example, see Brown, et al. (1979) Methods in Enzymology, Academic Press, N.Y., Vol. 68, pgs. 109-151. A DNA sequence encoding FLINT can be generated using a conventional DNA synthesizing apparatus such as the Applied Biosystems Model 380A or 380B DNA synthesizers (commercially available from Applied Biosystems, Inc., 850 Lincoln Center Drive, Foster City, CA 94404). It may be desirable in some applications to modify the coding sequence of the FLINT protein so as to incorporate a convenient protease sensitive cleavage site, e.g., between the signal peptide and the structural protein facilitating the controlled excision of the signal peptide from the fusion protein construct.

A gene encoding FLINT may also be created by using the polymerase chain reaction (PCR) using suitable primers designed in accordance with SEQ ID NO:3 (FLINT cDNA). The template can be a cDNA library from a tissue that expresses FLINT, for example (commercially available from Clonetech or Stratagene). Such methods are well known in the art, *c.f.* Maniatis, et al. Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Press, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York (1989) herein incorporated by reference.

The constructed or isolated DNA sequences are useful for expressing FLINT either by direct expression or as a fusion protein. When the sequences comprise a fusion gene construct, release of FLINT will require enzymatic or chemical cleavage from the fusion partner. A variety of peptidases which cleave a polypeptide at specific sites or digest the peptides from the amino or carboxy termini (e.g. diaminopeptidase) of the peptide chain are known. Furthermore, particular chemicals (e.g. cyanogen bromide)

will cleave a polypeptide chain at specific sites. The skilled artisan will appreciate the modifications necessary to the amino acid sequence (and synthetic or semi-synthetic coding sequence if recombinant means are employed) to incorporate site-specific internal cleavage sites. See U.S. Patent No. 5,126,249; Carter P., Site Specific Proteolysis of Fusion Proteins, Ch. 13 in Protein Purification: From Molecular Mechanisms to Large Scale Processes, American Chemical Soc., Washington, D.C. (1990).

Construction of suitable vectors containing the desired coding and control sequences employ standard ligation techniques. Isolated plasmids or DNA fragments are cleaved, tailored, and religated in the form desired to form the plasmids required.

In general, plasmid vectors containing promoters and control sequences which are derived from species compatible with the host cell are used with these hosts. The vector ordinarily carries a replication origin and one or more sequences for selection of transformed cells.

The desired coding sequence is inserted into an expression vector in the proper orientation to be transcribed from a promoter and ribosome binding site, both of which should be functional in the host cell in which the protein is to be expressed.

In general, procaryotes are used for cloning of DNA sequences in constructing the vectors useful in the invention. For example, E. coli K12 strain 294 (ATCC No. 31446) is particularly useful. Other microbial strains which may be used include E. coli B and E. coli X1776 (ATCC No. 31537). These examples are illustrative rather than limiting.

The DNA molecules may also be recombinantly expressed in eukaryotic expression systems. Preferred promoters for mammalian host cells may be obtained from various sources, for example, the genomes of viruses such as: polyoma, Simian Virus 40 (SV40), adenovirus, retroviruses, hepatitis-B virus and most preferably cytomegalovirus, or from heterologous mammalian promoters, e.g. •-actin promoter. The early and late promoters of the SV40 virus are conveniently obtained as an SV40 restriction fragment which also contains the SV40 viral origin of replication. Fiers, et al., Nature, 273:113 (1978). The entire SV40 genome may be obtained from plasmid pBRSV, ATCC 45019. The immediate early promoter of the human cytomegalovirus may be obtained from plasmid pCMBb (ATCC 77177). Of course, promoters from the host cell or related species also are useful herein.

Transcription of the DNA by higher eucaryotes is increased by inserting an enhancer sequence into the vector. Enhancers are cis-acting elements of DNA, usually about 10-300 bp, that act on a promoter to increase its transcription. Enhancers are relatively oriented and positioned independently and have been found 5' (Laimins, L. et al., PNAS 78:993 (1981)) and 3' (Lusky, M. L., et al., Mol. Cell Bio. 3:1108 (1983)) to the transcription unit, within an intron (Banerji, J. L. et al., Cell 33:729 (1983)) as well as within the coding sequence itself (Osborne, T. F., et al., Mol. Cell Bio. 4:1293 (1984)). Many enhancer sequences are now known from mammalian genes (globin, RSV, SV40, EMC, elastase, albumin, alpha-fetoprotein and insulin). Typically, however, one will use an enhancer from a eukaryotic cell virus. Examples include the SV40 late enhancer, the cytomegalovirus early promoter

enhancer, the polyoma enhancer on the late side of the replication origin, and adenovirus enhancers.

Expression vectors used in eukaryotic host cells (yeast, fungi, insect, plant, animal, human or nucleated cells from other multicellular organisms) will also contain sequences necessary for the termination of transcription which may affect mRNA expression. These regions are transcribed as polyadenylated segments in the untranslated portion of the mRNA encoding protein. The 3' untranslated regions also include transcription termination sites.

Expression vectors may contain a selectable marker. Examples of suitable selectable markers for mammalian cells are dihydrofolate reductase (DHFR, which may be derived from the BglII/HindIII restriction fragment of pJOD-10 [ATCC 68815]), thymidine kinase (herpes simplex virus thymidine kinase is contained on the BamHI fragment of vP-5 clone [ATCC 2028]) or neomycin (G418) resistance genes (obtainable from pNN414 yeast artificial chromosome vector [ATCC 37682]). When such selectable markers are successfully transferred into a mammalian host cell, the transfected mammalian host cell can survive if placed under selective pressure. There are two widely used distinct categories of selective regimes. The first category is based on a cell's metabolism and the use of a mutant cell line which lacks the ability to grow without a supplemented media. Two examples are: CHO DHFR$^-$ cells (ATCC CRL-9096) and mouse LTK$^-$ cells (L-M(TK-) ATCC CCL-2.3). These cells lack the ability to grow without the addition of such nutrients as thymidine or hypoxanthine. Because these cells lack certain genes necessary for a complete nucleotide synthesis pathway, they cannot survive unless the missing nucleotides are provided in a supplemented

media. An alternative to supplementing the media is to introduce an intact DHFR or TK gene into cells lacking the respective genes, thus altering their growth requirements. Individual cells which were not transformed with the DHFR or TK gene will not be capable of survival in nonsupplemented media.

A suitable vector for eucaryotic expression is pRc/CMV. pRc/CMV is commercially available from Invitrogen Corporation, 3985 Sorrento Valley Blvd., San Diego, CA 92121. To confirm correct sequences in plasmids constructed, the ligation mixtures are used to transform E. coli K12 strain DH10B (ATCC 31446) and successful transformants selected by antibiotic resistance where appropriate. Plasmids from the transformants are prepared, analyzed by restriction and/or sequence by the method of Messing, et al., Nucleic Acids Res. 9:309 (1981).

Host cells may be transformed with the expression vectors of this invention and cultured in conventional nutrient media modified as appropriate for inducing expression from a promoter, selecting transformants, or amplifying genes. Suitable culture conditions, temperature, pH and the like, are readily apparent to the ordinarily skilled artisan. The techniques of transforming cells with the aforementioned vectors are well known in the art and may be found in such general references as Maniatis, et al., Molecular Cloning: A Laboratory Manual, Cold Spring Harbor Press, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York (1989), or Current Protocols in Molecular Biology (1989) and supplements.

Suitable host cells for expressing the vectors encoding the claimed proteins in higher eucaryotes include: African green monkey kidney line cell line transformed by

SV40 (COS-7, ATCC CRL-1651); transformed human primary embryonal kidney cell line 293,(Graham, F. L. et al., J. Gen Virol. 36:59-72 (1977), Virology 77:319-329, Virology 86:10-21); baby hamster kidney cells (BHK-21(C-13), ATCC CCL-10, Virology 16:147 (1962)); Chinese hamster ovary cells CHO-DHFR$^-$ (ATCC CRL-9096), mouse Sertoli cells (TM4, ATCC CRL-1715, Biol. Reprod. 23:243-250 (1980)); African green monkey kidney cells (VERO 76, ATCC CRL-1587); human cervical epitheloid carcinoma cells (HeLa, ATCC CCL-2); canine kidney cells (MDCK, ATCC CCL-34); buffalo rat liver cells (BRL 3A, ATCC CRL-1442); human diploid lung cells (WI-38, ATCC CCL-75); human hepatocellular carcinoma cells (Hep G2, ATCC HB-8065);and mouse mammary tumor cells (MMT 060562, ATCC CCL51).

In addition, unicellular eukaryotes such as yeast may also be used. *Saccharomyces cerevisiae*, or common baker's yeast is the most commonly used eukaryotic microorganism, although a number of other strains are commonly available. For expression in *Saccharomyces*, the plasmid YRp7, for example, (ATCC-40053, Stinchcomb, et al., Nature 282:39 (1979); Kingsman et al., Gene 7:141 (1979); Tschemper et al., Gene 10:157 (1980)) is commonly used. This plasmid already contains the trp gene which provides a selection marker for a mutant strain of yeast lacking the ability to grow in tryptophan, for example ATCC no. 44076 or PEP4-1 (Jones, Genetics 85:12 (1977)).

Suitable promoter sequences for expression in yeast include the promoters for 3-phosphoglycerate kinase (found on plasmid pAP12BD ATCC 53231 and described in U.S. Patent No. 4,935,350, June 19, 1990) or other glycolytic enzymes such as enolase (found on plasmid pAC1 ATCC 39532), glyceraldehyde-3-phosphate dehydrogenase (derived from

plasmid pHcGAPC1 ATCC 57090, 57091), *Zymomonas mobilis* (U.S. Patent No. 5,000,000 issued March 19, 1991), hexokinase, pyruvate decarboxylase, phosphofructokinase, glucose-6-phosphate isomerase, 3-phosphoglycerate mutase, pyruvate kinase, triosephosphate isomerase, phosphoglucose isomerase, and glucokinase.

Other yeast promoters, which contain inducible promoters having the additional advantage of transcription controlled by growth conditions, are the promoter regions for alcohol dehydrogenase 2, isocytochrome C, acid phosphatase, degradative enzymes associated with nitrogen metabolism, metallothionein (contained on plasmid vector pCL28XhoLHBPV ATCC 39475, U. S. Patent No. 4,840,896), glyceraldehyde 3-phosphate dehydrogenase, and enzymes responsible for maltose and galactose (GAL1 found on plasmid pRY121 ATCC 37658) utilization. Suitable vectors and promoters for use in yeast expression are further described in R. Hitzeman et al., European Patent Publication No. 73,657A. Yeast enhancers such as the UAS Gal from *Saccharomyces cerevisiae* (found in conjunction with the CYC1 promoter on plasmid YEpsec--hI1beta ATCC 67024), also are advantageously used with yeast promoters.

The following examples are provided to further illustrate the preparation of the formuations of the invention. The scope of the invention is not construed as merely consisting of the following examples.

EXAMPLE 1

Preparation of FLINT-Zinc Formulations

About 20 mg of FLINT is completely dissolved in 32 mL of an aqueous solution containing 16 mg/mL glycerin and 2 mg/mL phenol and passed through a sterile 0.2 μ

filter. An aqueous solution containing 100 mg/mL of zinc in water is prepared from zinc chloride. Dilutions are made to prepare 10 mg/mL zinc and 1 mg/mL zinc solutions. Five 6-mL aliquots of the FLINT solution is mixed with the zinc solutions as shown in Table I:

Table I

Sample	mL of 1 mg/mL zinc added	ML of 10 mg/mL zinc added	ML of 100 mg/mL zinc added	ml of H_2O added	Total mg/mL zinc concentration
A	0	0	0	100	0
B	17	0	0	83	0.0027
C	0	33	0	67	0.054
D	0	0	19	81	0.30
E	0	0	92	8	1.50

Each formulation is adjusted to pH 7.48 ± 0.03 using small volumes of 2N and 5N sodium hydroxide and stored at 4°C. Sample A is completely clear while samples B through E are cloudy suspensions.

EXAMPLE 2

Analysis of Zinc Formulations

Size-exclusion chromatography is performed on the centrifuged supernatants of Samples A through E of Example 1. For these analyses, 100 uL of the supernatants are injected onto an analytical Superdex-75® (3.2/30, Pharmacia) column equilibrated in PBS (Dulbecco's Phosphate-Buffered Saline, GibcoBRL). The column is eluted at ambient temperature at 0.5 mL/min and the protein in the eluant monitored at 214 nm.

EXAMPLE 3

Biological Activity of the Zinc Formulations

A FLINT bioassay measuring cell survival (i.e. prevention of apoptosis) is performed in a 96 well plate format with reactions of 100 µl/well. 25 µl of Jurkat cells ($5X10^4$ cells/well) is mixed with 25 µl of recombinant human FasL (final concentration 150ng/ml) and 50 µl of FLINT samples in Example 1. Cells are incubated at 37°C over night. Twenty µl of MTS tetrazolium compound (U.S. Pat. No. 5,185,450 assigned to the Univ. of South Florida and exclusively licensed to Promega Corporation, Madison, WI) is added to each well and the incubation carried out for 2h at 37°C. Absorbance at 490 nm is recorded using a plate reader.

EXAMPLE 4

Large Scale FLINT Polypeptide Purification

Large scale production of FLINT was carried out by first growing stable clones stable pIG1-FLINT-containing AV12 RGT 18 cells in several 10 liter spinners. After reaching confluency, cells were further incubated for 2-3 more days to secrete maximum amount of FLINT into media. Media containing FLINT was adjusted to 0.1 % CHAPS and concentrated in an Amicon ProFlux M12 tangential filtration system to 350 ml. The concentrated media was adjusted to pH 6.0 and passed over a SP Sepharose Fast Flow (Pharmacia, 50 ml) at a flow rate of 3 ml/min. The column was washed with buffer A (20 mM MOPS, 0.1 % CHAPS, pH 6.0) until the absorbance (280 nm) returned to baseline and the bound polypeptides were eluted with a linear gradient from 0.1 M-0.3 M NaCl (in buffer A) developed over 40 min. followed by a linear gradient from 0.3 to 0.5 M NaCl (in buffer A) developed over 40 min. Fractions containing FLINT were

pooled and passed over a 1 cm x 15 cm Vydac C4 column equilibrated with 0.1 % TFA/H_2O. The bound FLINT was eluted with a linear gradient 10 % to 35 % CH_3CN/0.1 % TFA over 30 min. followed by a linear gradient from 35 % to 50 % CH_3CN/0.1 % TFA over 20 min. Fractions containing FLINT were pooled, concentrated under vacuum to approximately 2 ml and applied to a Superdex 75 (Hi Load 16/60, Pharmacia) size exclusion column equilibrated with PBS (1 mM potassium phosphate, 3 mM sodium phosphate), 0.5 M NaCl, 10 % glycerol, pH 7.4 at a flow rate of 1.0 ml/min. Fractions containing FLINT were analyzed by SDS-PAGE and found to be greater than 95 % pure. The N-terminal sequence of FLINT was confirmed on the purified polypeptide.

EXAMPLE 5

IMAC Purification of R218Q from 293 EBNA Cells

FLINT analog R218Q was purified by IMAC chromatography from 3.4 liters of cell culture medium harvested from 293 EBNA cells that expressed R218Q. The FLINT analog was eluted from the IMAC column in a buffer containing PBS, o.5 M NaCl, 0.4 M imidazole, pH 7.4. The eluted material was dialyzed against a buffer containing PBS, 0.5 M NaCl, 10% glycerol, pH 7.4. The dialyzed solution turned cloudy suggesting that the protein had precipitated. This was confirmed experimentally by intrinsic tryptophan fluorescence.

This problem was resolved by resuspending the precipitated protein in PBS, 0.5 M NaCl, 10% glycerol, pH 7.4 and adding EDTA to a final concentration of 50 mM. The precipitated protein went back into solution as observed by visual observation and confirmed by tyrptophan fluorescense.

EXAMPLE 6

Effect of Divalent Cation on FLINT

FLINT was purified from either AV12 or 293 cell lines. Protein samples were stored in PBS at pH 7.4, 0.5 M

NaCl, and 10% glycerol. The effect of divalent cations, such as Ni^{2+}, Zn^{2+} and Ca^{2+}, was investigated using intrinsic tryptophan fluorescence intensity and fluorescence anisotropy. Since fluorescence anisotropy is very sensitive to the rotational correlation time of the molecule, the change in the value of anisotropy reflects change in the association of FLINT molecules upon addition of divalent cations.

Concentrations of FLINT were measured on an AVIV model 14DS spectrometer. Spectra were collected from 400 nm to 260 nm at 1-nm bandwidth and were corrected for the solvent and scatter using data obtained between 360 nm to 320 nm by the AVIV computer program Loggen. The peak absorbance at about 280 nm was divided by 0.786 mg^{-1} cm^{-1} to determine the concentration of the protein in a 1-cm pathlength cell. 5 mM $NiCl_2$ or $ZnCl_2$ or $CaCl_2$ stock solution was made by dissolving in H_2O the appropriate amount of solid $NiCl_2$, $ZnCl2_2$, or $CaCl_2$.

Tryptophan fluorescence intensity and fluorescence anisotropy were measured using an ISS PCI photon counting spectrofluorometer. A protein solution of about 0.1 mg/ml concentration was excited at 295 nm and the total intensity of fluorescence and fluorescence anisotropy was recorded using a 335 nm cutoff filter in a cell of 5 mm x 10 mm pathlength with a 8 nm excitation bandwidth. A small aliquot of 5 mM $NiCl_2$, $ZnCl_2$, or $CaCl_2$ stock was added to the protein sample in the cell to adjust the concentration of divalent cation concentration. The sample was then mixed by inverting the cuvette after each addition of divalent metal. The fluorescence signal intensity and anisotropy were determined as a function of divalent ion concentration.

The fluorescence intensity and anisotropy data obtained on FLINT as a function of $NiCl_2$ or $ZnCl_2$ is shown in Table I. Addition of either $NiCl_2$ or $ZnCl_2$ decreased the fluorescence intensity and increased the anisotropy, indicating an association of FLINT molecules. The association of FLINT molecules upon addition of $ZnCl_2$ is reversible by addition of 2 mM EDTA, as indicated by the decrease of anisotropy to the initial anisotropy value in the absence of $ZnCl_2$.

Table I. Typtophan fluorescence intensity and anisotropy of FLINT as a function of $NiCl_2$ or $ZnCl_2$ concentration.

[NiCl2] uM	Intensity	Anisotropy	[ZnCl2] uM	Anisotropy
0	669978	0.1357	0	0.1344
5	648081	0.14	5	0.1304
10	628453	0.1368	10	0.1273
20	578457	0.1396	20	0.1342
40	548057	0.1416	40	0.1462
80	514699	0.1461	80	0.1724
100	457960	0.1527	100	0.1884
200	443962	0.1578	200	0.2172
400	361070	0.1671	400	0.2436
+ 2 mM EDTA	442029	0.1528	2 mM EDTA	0.1338

This example shows that divalent cations, such as Ni^{2+}, Zn^{2+}, and Ca^{2+}, interact with FLINT to cause association of FLINT molecules. Zn^{2+} causes reversible precipitation and can be used in the purification of His-tagged FLINT.

EXAMPLE 6

Treatment of Acute Liver Failure by a Complex of Divalent Cation and FLINT

Using mice, a model of liver damage is induced using a modification of the methods set out in Tsuji H., et al, 1997, Infection and Immunity, 65(5):1892-1898. FLINT is made according to Example 4. Briefly, BALB/c mice (Harlan) per each experimental group are given intravenous injections (the lateral tail vein) of 6 mg of D(+)-Galactosamine (Sigma, 39F-0539) in 100 µl of PBS (GIBCO-BRL) and 3 µg of Lipopolysaccharide B *E.coli* 026:B6 (LPS) (Difco, 3920-25-2) in 100 µl of PBS. The LPS is administered, via i.v. injection, 5 minutes after the galactosamine, which was administered i.v. After LPS challenge, the animals are injected intraperitoneally with FLINT (200 µg), or FLINT complexed with Zinc (as in Example 1). The survival rates of the mice are determined 24 and 48 hours after LPS injection.

When 400 ug of FLINT was administered i.p. to mice, 2 hours before challenge with LPS and GalN, 100% of the animals were alive 48 hours after LPS/GalN dosing (See Figure 6 WO 99/50413). In contrast, only 20% of those animals not treated with FLINT survived 48 hours. It is expected that the Zinc-FLINT formulation would be more potent than non-divalent formulated FLINT.

EXAMPLE 7

Treatment of Cerebral Ishcemia by a Complex of Divalent Cation and FLINT

Adult male gerbils (70 to 80 g body weight, Charles River Laboratories, Wilmington, MA) are anesthetized by i.p. injections of sodium pentobarbital

(Nembutal) 40 mg/kg, and additional i.p. injections of 10 mg/kg when necessary to maintain a surgical plane of anesthesia. Animals are placed on a thermostatically controlled heating blanket to maintain body temperature at 37 °C. The ventral surface of the neck is exposed, the fur shaved, and the skin cleaned with 2% iodine solution.

After the pre-surgical preparation, a midline incision is made, and the skin opened. The sternohyoid muscles are divided to expose and isolate the common carotid arteries (CCA) for clamping. Sterilized aneurysm clips (blade with 0.15 mm, closing force ~10 gm) are secured by means of a sterilized clip applier on both left and right CCA for 5 minutes. The clamps are then removed and the patency of the arteries checked visually. The wound in the neck is closed by surgical suture.

Immediately following the cerebral ischemia procedure and while the gerbil is still unconscious, the fur on the dorsal surface of the head is shaved and the skin cleaned with 2% iodine solution. Under surgical anesthesia, the gerbil's head is secured in a stable position by means of a stereotaxic apparatus (SA) and a midline incision is made to expose the skull. At a position 1 mm lateral and 1 mm posterior to the bregma, as guided by the vernier scale of the SA, the skull is thinned by a dental drill equipped with a drill bit of 0.5 mm in diameter. The thinned area is punctured with a microsyringe equipped with a 27-guage blunt needle inserted 3 mm deep for a bolus injection of 5 ul (0.63 mg/ml)of FLINT in phosphate buffer saline (PBS) or zinc-FLINt complex of Example 1.

After the bolus injection, the syringe needle is exchanged for an infusion cannula [3 mm in length] of a

brain infusion assembly connected to an Alzet osmotic pump (Alza Corp., Palo Alto, CA) which reservoir is placed under the skin on the shoulder of the gerbil. The infusion cannula is anchored on the surface of the skull using dental cement. The wound is closed by surgical suture. The Alzet osmotic pump containing FLINT solution (0.63 mg/ml) or zinc-FLINT is delivered continuously at a rate of 1 ul/h for 3 days. Gerbils are allowed to survive for 5 days (the surgery day is taken as day zero).

On the fifth day of survival, the gerbils are sacrificed in a CO2 chamber. Thoracotomy is performed for transcardiac perfusion of saline for 3 minutes and formaldehyde for 2 minutes. The brains are removed for histological processing following a standard procedure commonly adapted in the field. Coronal sections are obtained at approximately 1.7 mm posterior to the bregma. After staining with Cresyl violet, the sections are viewed under a microscope at 40x magnification for cell counter quantification of the intact hippocampal neurons along the dorsal CA1 regions (0.5 mm in length) of both hemispheres. Data are analyzed by Student t-Test and the Wilcox ranking test.

Results show that FLINT has a significant effect on neuronal survival compared to vehicle ($p=0.0039$ in t-Test; $p=0.0037$ in Wilcoxon Rank Sums) and is indistinguishable from normal controls. Zinc-FLINT complex would be expected to have enhanced potency.

What is claimed is:

1. A composition comprising a divalent metal cation and FLINT protein.

2. A composition as in claim 1 wherein said cation is selected from the group consisting of Zn^{+2}, Ca^{+2}, Ni^{+2}, Mn^{+2}, Fe^{+2}, Co^{+2}, and Cd^{+2}.

3. A composition of Claim 1, wherein the divalent metal cation is Zn^{+2}.

4. A pharmaceutical formulation comprising a composition of claim 1 in combination with one or more pharmaceutically acceptable carriers, diluents, or excipients.

5. A formulation of Claim 4, wherein the total cation concentration is 0.001 to 5.0 mg/mL.

6. A formulation of Claim 5, wherein the total cation concentration is 0.05 to 1.5 mg/mL.

7. A process for reducing aggregation of FLINT molecules comprising the step of removing divalent metal cation.

8. A process as in claim 7 wherein said FLINT molecules are in solution.

9. A process as in claim 7 wherein said cation is removed by the addition of EDTA.

10. A method for inducing oligomerization of FLINT molecules comprising the step of adding divalent metal cation.

11. A method for inducing aggregation of FLINT molecules comprising the step of adding divalent metal cation until said molecules precipitate.

SEQUENCE LISTING

<110> Witcher, Derrick
Tian, Yu
Atkinson, Paul

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